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ACCURACY OF CONE-BEAM COMPUTERIZED TOMOGRAPHY IN DETERMINING THE THICKNESS OF THE PALATAL MASTICATORY MUCOSA

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ACCURACY OF CONE-BEAM COMPUTERIZED TOMOGRAPHY IN DETERMINING THE THICKNESS OF THE PALATAL MASTICATORY MUCOSA

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science in Dentistry at Virginia Commonwealth University.

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Abstract

THE ACCURACY OF CONE-BEAM COMPUTERIZED IN DETERMINING THE THICKNESS OF THE PALATAL MASTICATORY MUCOSA

By Justin Mitchell Hardison, D.M.D.

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BACKGROUND: The aim was to compare the thickness of the palatal masticatory mucosa as determined on a cone-beam computerized (CBCT) scan versus thickness determined via bone-sounding.

METHODS: A total of twenty patients requiring palatal surgery participated. Thickness of the palatal tissue was measured at various points radiographically and clinically. The two techniques were compared to determine the agreement of the two measurement modalities.

RESULTS: Analysis of variance determined that there was no significant difference between the two methods. A small bias of the radiographic measurement being larger was found to be statistically significant (0.09 ± 0.69mm; $p < 0.0001$). Moreover, the

tissue thickness was shown to increase as the distance from the gingival margin increased and the tissue over the molars was thinner than the tissue over the premolars.

CONCLUSIONS: CBCT can be used to accurately determine the soft tissue thickness of the palatal masticatory mucosa with minimal bias.

Introduction

Gingival recession is characterized by the displacement of the soft tissue gingival margin apical to the cementoenamel junction (CEJ). The condition is widespread, as prior studies have indicated that prevalence ranges from 38% to 90% within the general population and 9% to 56% of teeth within an affected individual.[1-3] In an epidemiological study of over 9600 subjects, Albander and Kingman showed that the overall prevalence of recession persons in 30 to 90 year olds was 58%. This study also demonstrated that prevalence increased with age and was more prevalent in males than in females and in African-Americans versus Caucasians.[4] Gingival recession is multifactorial; however, there are many predisposing factors,[1-3] including increasing age,[4-6] bony dehiscences and fenestrations,[7] tooth position in the arch,[8] orthodontic tooth movement,[9,10] mechanical trauma such as use of a hard toothbrush[11] and increased frequency of toothbrushing,[12] direct trauma from malocclusion,[13] width and thickness of keratinized tissue,[14] partial denture use,[15] high muscle attachment and frenal pull,[16,17] restorative dentistry,[18] repeated root planing in shallow pockets,[19] calculus,[20] periodontal disease,[21] and smoking.[22]

Gingival recession presents problems for the clinician and patient alike, as it has been linked to root caries, plaque retention, gingival bleeding, and cervical abrasion. Additional patient concerns associated with recession include dentin hypersensitivity, fear of tooth loss, and poor esthetics.[1,2,23] The exposed root surface that results from the apical displacement of the soft tissue margin is the cause of these problems and therefore, surgical techniques have been developed to gain root coverage.

These techniques are the free gingival graft (FGG)[24] and the subepithelial connective tissue graft (SCTG)[25]. Other techniques that have been performed to gain root coverage are guided tissue regeneration (GTR)[26] and pedicle grafts including laterally positioned flaps,[27] double papilla flaps,[28] coronally positioned flaps,[29] and semilunar flaps.[30] Recently, the use of acellular dermal matrix has become a popular allograft technique to gain root coverage with predictable results.[31]

Soft tissue grafting is a long-standing, acceptable treatment for gingival recession. The SCTG is frequently referred to as the "gold standard", showing clinical effectiveness of 91% of root surface coverage, compared to 72% with FGG and 76-83% with GTR.[32,33] Due to its high success and predictability, many modifications of the SCTG exist. Langer and Langer[25] introduced the SCTG with an overlaying coronally positioned flap; Raetzke[34] proposed the "envelope" technique; Zabalegui[35] used a tunnel approach with a SCTG to treat multiple adjacent recession defects, and; Blanes and Allen[36] combined a SCTG with a bilateral pedicle-flap-tunnel.

The common element of all modifications of SCTG is the use of autogenous connective tissue that is frequently harvested from the palatal masticatory mucosa.[37-39] Moreover, in addition to being an integral donor site for root coverage procedures, the palate serves as a donor site for the FGG. These grafts are used to augment the width of keratinized tissue around teeth[39] or implants and for augmenting localized alveolar ridge deficiencies.[40]

A critical aspect in the treatment planning of these cases is the determination of the thickness of the graft donor site, since the thickness of tissue grafted from the palate to the recipient site directly affects the surgical outcome.[6,41] Revascularization of the graft may be prevented if the donor tissue is too thick and graft shrinkage may occur if the tissue is too thin.[42] To prevent these undesirable outcomes, methods have been developed to help the clinician determine the thickness of the palatal masticatory mucosa prior to harvesting the graft. One such method is the use of ultrasonic measuring devices that transmit ultrasonic pulses through the soft tissue, and uses an echo of the pulse to calculate thickness.[43] Another frequently used method is the bone-sounding technique, a direct method that involves anesthetizing the patient and subsequently penetrating the palatal masticatory mucosa with either a periodontal probe or a needle to determine tissue thickness. When using a periodontal probe to determine the thickness of the palatal masticatory mucosa, Studer et al.[44] reported a measurement error of approximately 0.2 ± 0.4mm associated with this technique. Ursell[45] concluded that bone-sounding with a periodontal probe gave a highly accurate indication of bone levels measured at surgery with 93.25% of measurements being within 1mm. While highly accurate, a drawback to this method is that it is commonly performed immediately prior to surgery, as the patient must be anesthetized. This may possibly hinder appropriate treatment planning of the procedure,[46] as the clinician may find that there is not sufficient tissue thickness in the pre-anesthetized area.

In an attempt to assist with treatment planning, less invasive techniques to determine the thickness the palatal masticatory mucosa have been developed using computerized tomography (CT).[47] Cone-beam computerized tomography (CBCT), in particular, has been used since its development in the 1990s for imaging of the maxillofacial region.[48] Compared to conventional CT systems, CBCTs produce a more focused beam, less radiation scatter,[49] and more rapid volumetric image acquisition,[50] along with being smaller in size and less expensive. Additionally, CBCT has become popular for 3-dimensional imaging in the dental field both because of its high spatial resolution and clear images on scans, and its relatively low radiation dose, which is similar to a full mouth series of periapical films[51] and well below that of classic CT.[52,53] Ludlow et al.[52] calculated the effective radiation dose of a CBCT unit to range from 0.045-0.487 mSv, which compares to the 0.150 mSv effective radiation dose associated with a full mouth radiographic examination. It is also approximately 1/15 that of the spiral CT which is used for maxillary and mandibular imaging.[53]

A benefit of the use of CBCT scans in dental imaging that has gained much attention in the recent literature is its accuracy in reproducing linear dental measurements.[53-56] Misch et al.[56] concluded that linear measurements of artificially-created osseous defects in the labial-lingual direction were similar when measured clinically with a caliper or radiographically using a CBCT scan. Fu et al.[57] compared the dimensions of soft tissue around extracted teeth measured with a caliper and a CBCT scan and found no difference between the clinical and radiographic measurements except for the palatal aspect of the teeth. Baumgaertel et al.[54] measured the distances between intraoral points with a digital caliper and compared them to measurements made on a CBCT scan and found them to be comparable, and Barriviera et al.[46] recently described a technique using CBCT to accurately visualize the dimensions of the palatal masticatory mucosa. In addition to accurately representing clinical measurements, data obtained from CBCT scans may indeed be more accurate than that obtained from bone-sounding, as pressure from a periodontal probe or needle may cause tissue distortion during bone-sounding.[47] More importantly, the ability of the clinician to evaluate the entirety of the palatal masticatory mucosa with a CBCT scan may provide the opportunity to choose the site from which an ideal graft can be harvested.[46] To the author's knowledge, the validity of CBCT scans in determining the thickness of the palatal masticatory mucosa, and the clinical relevance of this less invasive imaging modality, has not been verified. Therefore, the aim of this study is to compare the thickness of the palatal masticatory mucosa, as determined on a CBCT scan, to the actual anatomic thickness determined by a bone-sounding technique.

Materials and Methods

Patients

Twenty (20) healthy patients (10 males; 10 females; average age 53 years; range 26-77 years) requiring palatal surgery were recruited from the Virginia Commonwealth University (VCU) School of Dentistry Graduate Periodontics Clinic from January 2011-December 2011. Informed consents were obtained from all participants and the study was reviewed and approved by the Institutional Review Board at VCU. Inclusion criteria for participation in the study were the presence of a canine, two pre-molars, and the first molar on the side requiring palatal surgery. Subject exclusion criteria were: 1) history of palate surgery; 2) history or presence of pathology in the area being investigated; and 3) pregnancy.

Measurement Stent Fabrication

After the subject was deemed eligible, a maxillary impression was taken with alginate (Jeltrate PLUS, Dentsply International Inc., Milford, DE) impression material and poured in a Type III dental stone (Microstone, Whip Mix Corporation, Louisville, KY). Acrylic measurement guides (Clear Splint Biocryl, 0.5mm thickness, Great Lakes Orthodontics, LTD, Tanawanda, NY) were then fabricated on the cast model and trimmed appropriately to include all teeth present in the arch. Each stent was completely tooth-borne to prevent movement during measurements. Using a standardized UNC Probe (Hu-Friedy, Chicago, IL), measurements were made at distances of 2mm, 5mm, and 8mm from the mid-palatal point of the gingival margin for the canine, first and second premolars, and the first molar on the side that was to receive palatal surgery. A hole was subsequently punctured through the acrylic stent at each measurement point. Gutta-percha (Henry Schein Inc., Melville, NY) was used fill each measurement site (Figure 1). The purpose of the gutta-percha was to have a radio-opaque marker on the CBCT scan. This stent was subsequently used for all clinical and radiographic measurements.

Radiographic Measurements

All subjects wore the CBCT stent during the CBCT scan. During CBCT scans, patients were seated and had their heads and chins stabilized. A scan of the maxilla was taken using the CBCT (NewTom 9000, Verona, Italy) in the Periodontics Department, VCU School of Dentistry by a trained technician at 110KVp and 15mA for 36 seconds (voxel size: 0.25mm; grayscale: 12 bis). The reconstructed images were generated using a computer software package (Keystone EasyGuide, Keystone Dental, Inc., Burlington, MA). Each gutta-percha point was visualized using a sagittal view and measurements of the soft tissue thickness were made at each point by one investigator (JMH) and recorded. All measurements were made perpendicular to the palatal soft tissue (Figure 2). Twelve total radiographic measurements were taken on each scan and labeled as follows to correspond with the measurement guide: Canine-2mm (RCan-2; radiographic measurement of the canine, 2mm distance from gingival margin), -5mm (RCan-5), -8mm (RCan-8); 1-Pre-molar-2mm (R1PM-2; radiographic measurement of the 1st premolar, 2mm from the gingival margin), -5mm (R1PM-5), -8mm (R1PM-8); 2-Premolar-2mm

(R2PM-2; radiographic measurement of the 2nd premolar, 2mm from the gingival margin), -5mm (R2PM-5), -8mm (R2PM-8); Molar-2mm (RM-2; radiographic measurement of the molar, 2mm from the margin), -5mm (RM-5), -8mm (RM-8).

Clinical Measurements

On the day of surgery, each patient was anesthetized for palatal surgery using 2% xylocaine with epinephrine (Lidocaine HCl 2% with epinephrine 1:100,000, Henry Schein, Melville, NY). Anesthetic was administered slowly as a greater palatine nerve block to reduce unintended volume increases in the palatal mucosa. Approximately 30 minutes after anesthetic administration, the gutta-percha was removed from the CBCT stent to expose the measurement points and the stent was aligned correctly in the patient's mouth. The thickness of the palatal mucosa was then determined via bone-sounding through each measurement point perpendicular to the palatal tissue using a standardized UNC Probe (Hu-Friedy, Chicago, IL) and recorded by one investigator (JMH). Measurements were rounded to the nearest ½mm when the value was not exactly on a marking line (Figure 3). Twelve total clinical measurements were taken on each subject and labeled as follows to correspond with the measurement guide: Canine-2mm (CCan-2; clinical measurement of the canine, 2mm distance from gingival margin), -5mm (CCan-5), -8mm (CCan-8); 1-Pre-molar-2mm (C1PM-2; clinical measurement of the 1st premolar, 2mm from the gingival margin), -5mm (C1PM-5), -8mm (C1PM-8); 2-Premolar-2mm (C2PM-2; clinical measurement of the 2nd premolar, 2mm from the margin), -5mm (C2PM-5), -8mm (C2PM-8); Molar-2mm (CM-2; clinical measurement of the molar, 2mm from the margin), -5mm (CM-5), -8mm (CM-8).

Statistical Analysis

The primary aim of the data analysis was to compare the agreement of two modalities for measurement of the thickness of the palatal masticatory mucosa (radiographic measurements as determined on a CBCT scan, and clinical measurements as determined by a bone-sounding technique). The data were analyzed to determine factors that may influence the agreement of the measurement methods such as location on the palate (both the distance from a tooth and the tooth type the measurement was taken from) and depth of the palatal tissue (estimated as an average of both types of measures). Two separate analysis of variance (ANOVA) were used to accomplish this goal: 1) the absolute difference of the two measures as the response variable, and the subject as a random error term; this will account for correlation of measures within an individual and how agreeable the two measurement modalities were and; 2) the difference between measures as the response variable, and the subject as a random error term; this will determine potential bias between the two different measurement methods and/or influences of other effects on that bias, such as distance from a tooth and the tooth type. To describe concordance of the two measures and to show potential bias, a Bland-Altman plot was used. In this a graphical representation of two measurement techniques, the differences between the two techniques (ex: radiographic measurement depth – clinical measurement depth at 2mm from the gingival margin of the canine in Subject 1; Y-axis) are plotted against the means of the two techniques at the same measurement point (X-axis).[58]

A secondary aim of the analysis was to determine the actual thickness of the palatal tissue in different locations on the palate. For this goal, means and standard deviations of the measures are described. To evaluate influences of factors on the depth of the palatal tissue an ANOVA was used, with the mean of both measures as the response variable and the subject as a random error term.

Results

Patients

The study subjects were evenly divided based on gender (10 males; 10 females). Overall, the age distribution was wide, ranging from 26 to 77 with a mean of 53, and a median of 54.

Comparison of Clinical and Radiographic Measurements

Analysis of variance with the absolute difference of the two measures as the response variable, and the subject as a random error term, could not find any significant effects. This indicates that the location on the palate (both the distance from a tooth and the tooth type the measurement was taken from), and thickness of the palatal tissue (estimated as an average of both types of measures), did not influence the size of the difference between the two measurement modalities (data not shown). However, when the difference between the measures was used as the response variable, significant effects were found. A small bias of the radiographic measure being larger was found to be statistically significant (0.09 ± 0.69mm; $p < 0.0001$). Moreover, significant effects of the location on the palate (both distance from a tooth and the tooth type the measurement was taken from) were also shown, but the interaction between them was not shown to be significant. It appears that the bias for a larger radiographic measure increased as the distance from the tooth increased (Table 1). The relationships were less clear for tooth type, where the second premolar had a larger radiographic measure than other tooth types (Table 2).

Bland-Altman Plot of Differences Between Two Techniques vs Means of Two Techniques

The difference between the measurement modalities (Y-axis) is plotted against the mean depth of the same measurement point (X-axis). Individual colors of the markings are as follows: 1) red dots indicate measurements taken 2mm from the gingival margin; 2) green dots indicate measurements taken 5mm from the gingival margin; 3) blue markings indicate measurements taken 8mm from the gingival margin; 4) green lines indicate both the estimate of the slope (solid line; found to be not statistically significant from 0), and the 95% confidence interval (dotted line) between the difference (radiographic-clinical measurements) and the mean depth of all measurements, and; 5) the solid red line is the estimate of the overall bias of the difference (radiographic measures being larger than the clinical measures; $p < 0.0001$) (Figure 4).

Thickness of Palatal Tissue in Different Locations on the Palate

The thickness of the tissue, as estimated by the mean of both measures, was influenced by palatal location. Both the distance from a tooth and tooth type were significantly related to depth ($p < 0.0001$), but the interaction between these two variables was not significant (data not shown). The tissue became thicker as the distance from the tooth increased (Table 3) and the tissue measured at the premolars was thicker than that measured at the molar or canine areas (Table 4).

Discussion

Over the past two decades, the use of cone-beam computerized tomography (CBCT) for imaging of the maxillofacial region has increased dramatically.[48] This growth can be attributed to several factors: 1) compared to conventional computerized tomography (CT) systems, the CBCT produces a more focused beam with less radiation scatter[49]; 2) CBCTs are smaller and less expensive than conventional CT systems, and most importantly; 3) CBCT scans have been shown to accurately reproduce linear dental measurements.[54,56] Baumgaertel et al.[54] compared the results of ten interfacial measurements (including overbite, overjet, and maxillary and mandibular intermolar and intercanine widths) taken with a high-precision digital caliper, to a CBCT scan on thirty human skulls and found that there was no significant difference between measurement modalities. Lascala et al.[50] compared radiographic measurements of the distance between internal and external anatomical sites on dry skulls to clinical measurements taken with a caliper, and concluded that CBCT imaging is reliable for linear evaluation of facial structures. However, despite the abundance of literature proclaiming the accuracy of CBCT scans in determining linear interfacial hard tissue measurements, until recently there has been a lack of work investigating the accuracy of CBCT imaging of soft tissue measurements.

Barriviera et al.[46] recently described a technique using CBCT that accurately visualized the dimensions of the palatal masticatory mucosa, thus enabling the clinician to make linear measurements of the soft tissue covering the palate. The clinical significance of this finding was that CBCT scans may be useful in the treatment planning of cases where the thickness of the palatal tissue is paramount, such as gingival grafting with either free gingival grafts (FGG) or subepithelial connective tissue grafts (SCTG). However, no attempt was made to compare radiographic to clinical measurements. To date, the most common method of determining the thickness of the palatal tissue prior to harvesting a tissue graft is to bone-sound, a highly accurate method, but one that requires patient anesthetization. Studer et al.[44] investigated the accuracy of bone-sounding with a periodontal probe at multiple sites on the hard palate and maxillary tuberosity region and reported an error of approximately 0.2 ± 0.4mm over 744 total measurements. However, because bone-sounding must be performed while the patient is anesthetized, thus hindering appropriate treatment planning, as a clinician may find that there is insufficient tissue thickness in the anesthetized site, it may be considered a less than ideal method of soft tissue measurement. Thus, the primary aim of this study was to determine if the thickness of the palatal masticatory mucosa as determined from a CBCT scan was comparable to the actual anatomic thickness of the same distance measured by a bone-sounding technique.

In the present study, no significant difference was found between the clinical and radiographic measurements of the palatal masticatory mucosa for either location on the palate or thickness of the palatal tissue. This indicates that CBCT is a reliable measurement modality for the palatal tissue. While there remains a lack of literature addressing the accuracy of CBCT imaging of soft tissue measurements, the findings of the current study are consistent with the current body of literature stating that CBCT scans are reliable for hard tissue linear dental measurements.[50,54,56] However, when bias of one measurement modality versus another was investigated, the current study found a small bias of the radiographic measure being larger (0.09 ± 0.69mm). This is in contrast to contemporary publications where CBCT measurements underestimate the true anatomic measurement,[50,54] but these results are not clinically significant.

The Bland-Altman Plot (Figure 4) is a graphical representation of agreement between the two different measurement modalities (i.e. radiographic measurements versus clinical measurements).[58] The following conclusions can be drawn from this plot: 1) there is no significant difference between radiographic and clinical measurements because the vast majority of points fall within the 95% confidence interval (dotted green lines) around a difference (radiographic measurements – clinical measurements) of zero and; 2) there is a slight bias for the radiographic measurements being larger than the clinical measurements, as the solid red line (estimate of overall bias) is greater than a difference of zero.

A secondary aim of the current study was to determine the actual thickness of the soft tissue in different palatal locations. The results of this study showed that the tissue became thicker as the distance from the tooth increased and that the tissue measured at the premolars was deeper than that measured at the molars. This is in agreement with

Studer et al.[44] who showed that the mean tissue thickness increased, as the distance from the gingival margin increased and that the palatal tissue over the root of the maxillary first molar was significantly thinner than all positions in the hard palate. Müller et al.[43] also showed that palatal tissue was thicker at premolars when compared to 1st molars, which is consistent with the results found in this study.

In conclusion, this study demonstrated that CBCT can be used to accurately determine the soft tissue thickness of the palatal masticatory mucosa with minimal bias, as measurements taken from a CBCT scan were shown to be similar to clinical measurements made via bone-sounding. The current results indicate that a CBCT scan can be used as a non-invasive method of determining palatal tissue thickness. The clinical significance of this finding is that the clinician can potentially use a CBCT scan to determine the location from where a soft tissue graft may be harvested, thus enabling more accurate treatment planning of procedures prior to the surgical appointment.

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Table 1. Difference in Measurement Modalities (Radiographic – Clinical) at Varying Distances from the Gingival Margin

Mean Distance from Gingival Margin	**Least Squared Mean**	**Standard Error**
2mm	-0.28mm	0.11mm
5mm	0.06mm	0.11mm
8mm	0.49mm	0.11mm

Table 2. Difference in Measurement Modalities (Radiographic – Clinical) at Different Tooth Types

Tooth Type	Least Squared Mean	Standard Error
Canine	0.03mm	0.11mm
1st Premolar	0.13mm	0.11mm
2nd Premolar	0.40mm	0.11mm
1st Molar	-0.18mm	0.11mm

Table 3. Mean Depth of Palatal Tissue at Varying Distances from the Gingival Margin

Mean Distance from Gingival Margin	Least Squared Mean	Standard Error
2mm	2.98mm	0.12mm
5mm	3.79mm	0.12mm
8mm	4.57mm	0.12mm

Table 4. Mean Depth of Palatal Tissue at Different Tooth Types

Tooth Type	Least Squared Mean	Standard Error
Canine	3.58mm	0.12mm
1st Premolar	3.91mm	0.12mm
2nd Premolar	4.15mm	0.12mm
1st Molar	3.48mm	0.12mm

Figure 1: Measurement Stent

a. Stent on Cast; b. Stent Placed Prior to CBCT Scan

a.

b.

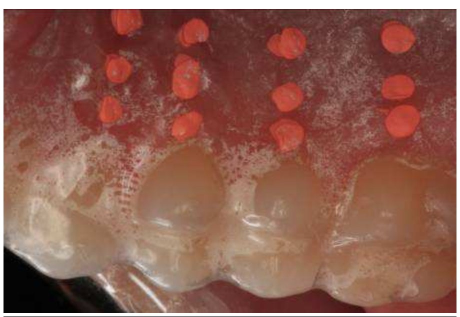
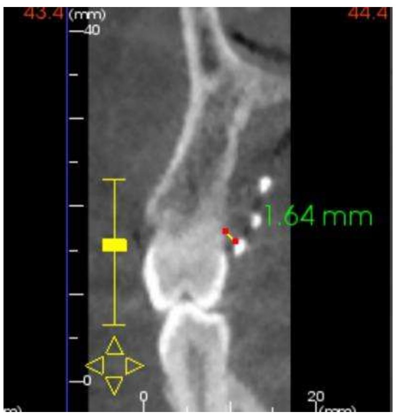


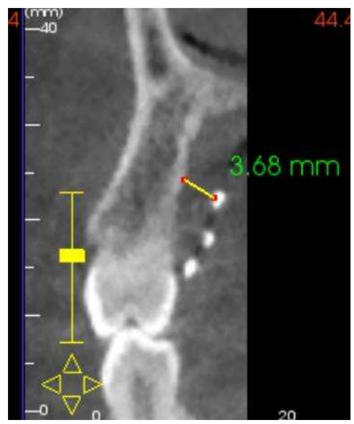
Figure 2. Radiographic Measurements

a. First Premolar 2mm Measurement; b. First Premolar 5mm Measurement; c. First Premolar 8mm Measurement

a.



c.



b.

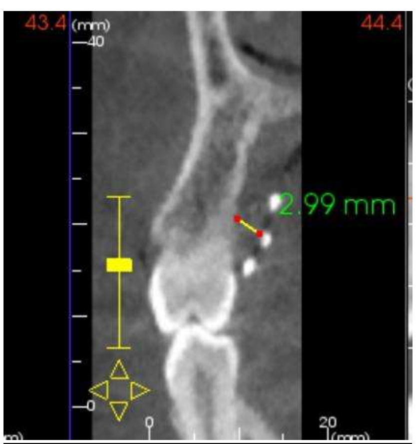
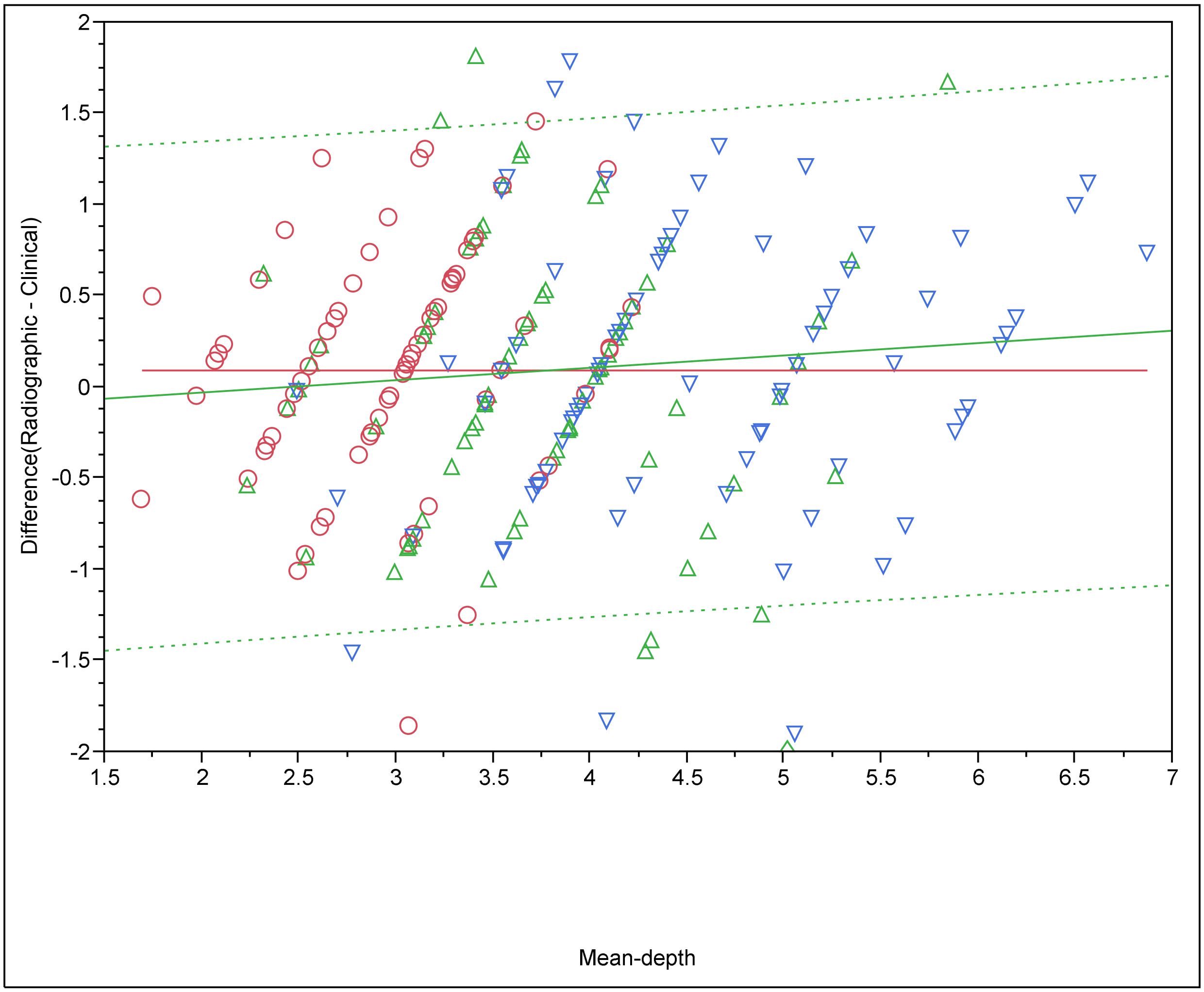


Figure 3. Clinical Measurement of a Maxillary First Premolar 2mm from the Gingival Margin

Figure 4. Bland-Altman Plot of Differences Between Two Techniques vs Means of Two Techniques



Vita

Justin Mitchell Hardison was born on September 12, 1981 in Hartford, Connecticut and is an American Citizen. He graduated from Conard High School in West Hartford, Connecticut in 1999. He received his Bachelor of Arts degree from Bowdoin College in Brunswick, Maine in 2003. He received his Doctor of Dental Medicine from the University of Connecticut School of Dental Medicine in Farmington, Connecticut in 2009.